Int. J. Econ. Environ. Geol. Vol. 8 (2) 28-34, 2017

Journal home page: www.econ-environ-geol.org

Open Access

ISSN: 2223-957X

Delineation and Assessment of Hab watershed, Balochistan, Pakistan through Geo-spatial Technology

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Received: *21 October, 2016* ***Accepted:*** *20 December, 2016*

Abstract: Water is one of the key elements of life and Pakistan is facing acute water shortage. The problem is more severe in the mega cities like Karachi and nearby areas in which industries and population are growing at a very high rate. Presently, Karachi is getting only about 55 percent of water against its fast increasing requirements leading to water crises in Karachi city. The Hab River is one of the main and important water supply sources for Hab industrial estate and Karachi. Therefore, it is extremely important to study this area with an aim to explore, develop and exploit its water resources for the current and upcoming requirements of the area. This paper is about the investigation of the potential of water resources in the Hab watershed through geo-informatics. Hydrological modeling has been done in GIS environment, which outlines a complete picture of Hab watershed and provides assessment of the potential of the watershed located in the Balochistan province of Pakistan. Watershed boundaries have been established and its area has been estimated in GIS environment. Considering the large area, Hab watershed has been categorized as macro watershed. Drainage characteristics of the watershed have been defined through GIS datasets, which were derived by performing drainage analysis on a terrain model. Other key contributions of the study include stream network analysis, flow accumulation and flow pattern analysis of the watershed.

Keywords: Geo-informatics, hydrological modeling, delineation, drainage network, watershed.

Introduction

Water is the basic element of life, without it there is no concept of life. This vital source is presently facing grave challenges for its existence on the face of earth (WHO, 2009). The Hab River is one of the main water supply sources for Karachi and Hab Estate (Aftab, 1997). No considerable investment has been made during last 32 years for exploration, preservation and development of water resources of the area. This area therefore, needs focused attention with respect to exploration, development and exploitation of its water resources. About 100 million gallons designed water supply to Karachi from Hab reservoir is intermittent and protracted for the last four years. Termination of water supply from this source has added more difficulties in water crises of Karachi (Daily Express Tribune, 2016). Hab watershed is considered one of the vital sources to be explored, developed and exploited for the present and future needs of the region (Sadaf, 2014).

This paper investigates the potential of water resources in Hab catchment through Geo-informatics. Main objective of this study is characterization of Hab watershed through hydrological modeling. GIS is one of the latest technologies, which provide efficient tools and environment for managing geographical data in digital format. The key elements include bringing the data in suitable form, undertaking spatial analysis, and modeling post processing outcomes (Goodchild, 1993). Hydrological parameters are very important and most significant tool for the assessment of water resources. Drainage analysis helps to analyze the characteristics of watershed like delineation, modeling, runoff modeling, suitable site selection for water recharge and discharge (Sreedevi et al., 2013; Javed et al., 2009; Thomas et al., 2012). Drainage network analysis provides the vital information about a basin, includes present and past geological variation, topographic information and structural information etc. Drainage analysis technique in GIS and Remote sensing environment has been adopted by many scientists and researchers (Grohmann, 2004; Magesh et al., 2011).

Integrated approach of GIS and Hydrological modeling has brought revolution in the field of hydrological analysis. These GIS based techniques and approaches are very fast and effective as compared to manual approaches and also give the comprehensive, reproducible and accurate analytical outputs/results. Many researchers have discussed in detail about the potential of GIS application in the field of water resources (Tribe, 1991; Walsh, 1992; Leipnik et al., 1993). GIS is very useful in the field of water resource management and its integration with hydrological modeling provides efficiently new dimensions for multi-objective analysis with precision (Band and

Moore, 1995; McDonnell, 1996). GIS is efficient tool for the mapping of water routing, its patterns, information about the network of channels, catchment/drainage area and its characteristics like divides, slope and other aspects etc (Jenson and Domingue, 1988; Mark, 1984; Moore et al., 1991; Martz and Garbrecht, 1992). Drainage network for watershed derivation from SRTM data is considered very reliable and important. Arc Hydro tool in GIS environment very effectively calculates the stream network of drainage basin.

Any geographical area which contributes water as a overland flow to rivers, streams, any pond, swamp, or sea is defined as a watershed. In short, catchment area which is completely drained by any stream and its network is known as watershed. It can be divided or segmented in many small watersheds. One part or segment of watershed is called sub watershed.

Study Area

The study has been conducted on the Hab River, which originates from Porali River System in Balochistan, Pakistan. It is located at the margin of Sindh and Balochistan provinces. Its geographical location is 24°80" S and 27°62" N, 66°67" W and 67°49" E. (Fig. 1, 2). Hab River originates from the Khuzdar mountain series approximately 200 miles in the north direction of Cape Monze and height from sea level is about

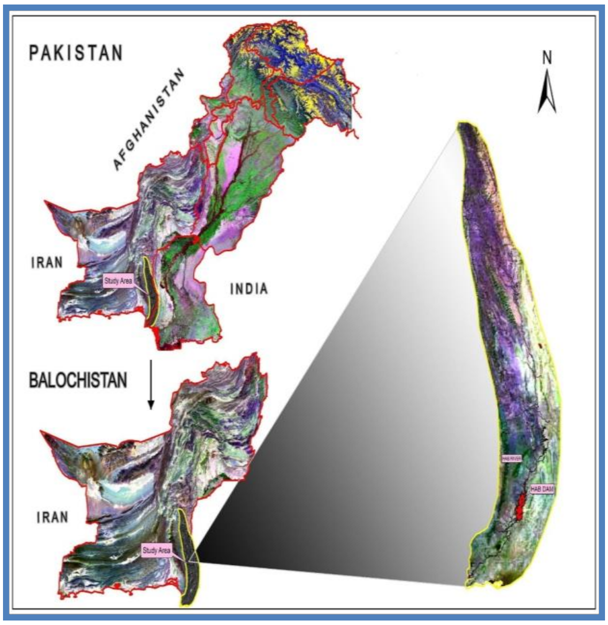

Fig.1 Location map of study area (Hab watershed).

6,000 ft. It is surrounded by mountains and is long and narrow in shape. The flow direction of Hab River is north south, just around the boundary of two provinces of Pakistan, Balochistan and Sindh and finally terminates in to the Arabian Sea (WAPDA, 1993).

The material and methodology used in this study can be categorized as following.

- Digital Data (Satellite imageries and DEM data)
- Arc Hydro System
- Hydrological modeling

Landsat Satellite Image

Satellite Remote Sensing (SRS) technology is very useful for scanning earth's surfaces and provides high resolution satellite images. In present study, Landsat

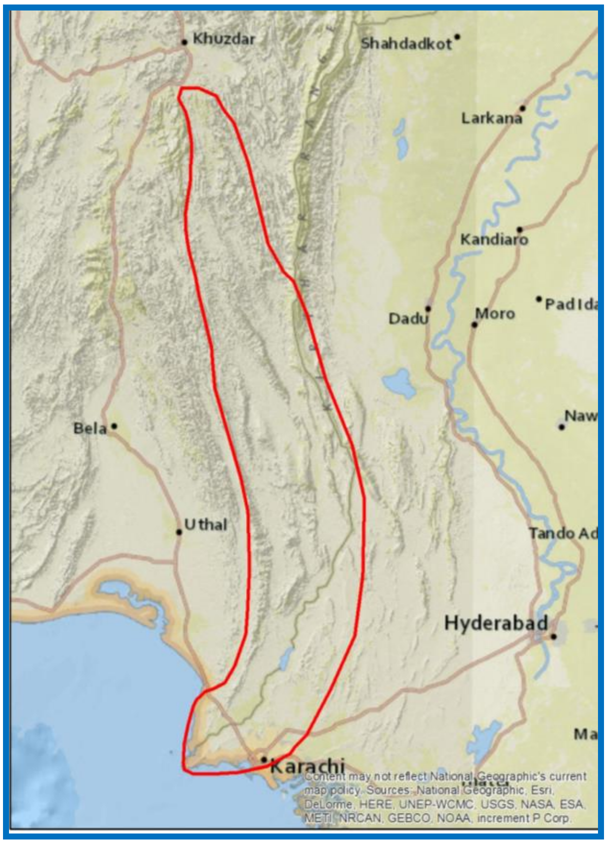

Fig. 2 Large view of study area.

images are used to project study area, which was downloaded through USGS website (http://earthexplorer.usgs.gov).

Digital Elevation Model (DEM)

Digital Elevation Models (DEM) is defined as grid-based GIS coverage representing elevation. It is used to display topographic information (USGS, 2012). 30 m DEM data have been utilized in this study for the Hydrological modeling.

Arc Hydro System

Arc Hydro system is used for water based analysis. It works in GIS environment and has a set of tools, which facilitate the analyses performed for water resource management and their hydrological modeling. For the assessment of a watershed, it is important to monitor the flow pattern and its effects across the area.

To understand the flow of water in a watershed, modeling is a tool, which gives the detailed information. It has the capacity to estimate many properties of a watershed like physical components of a basin, identification of sinks or holes, flow direction and accumulation, segmentation and stream networks creation. DEM data is very useful for the hydrological modeling of any watershed (Fig. 3).

Results and Discussion

Size of Hab Watershed

Boundaries of study area were defined and size was calculated in ArcGIS environment. The total precipitation has direct effect on small watershed (Youngbo and Florimond, 2004).

Drainage analysis of Hab watershed

Drainage analysis was done in GIS environment through a terrain model. As a result, many datasets were derived, which describe the basin of the Hab watershed in detail. Derived datasets include flow direction and accumulation, stream network segmentation, delineation and segmentation of watershed. These datasets provide a vector representation of stream network and catchment area, which help to develop a geometric network.

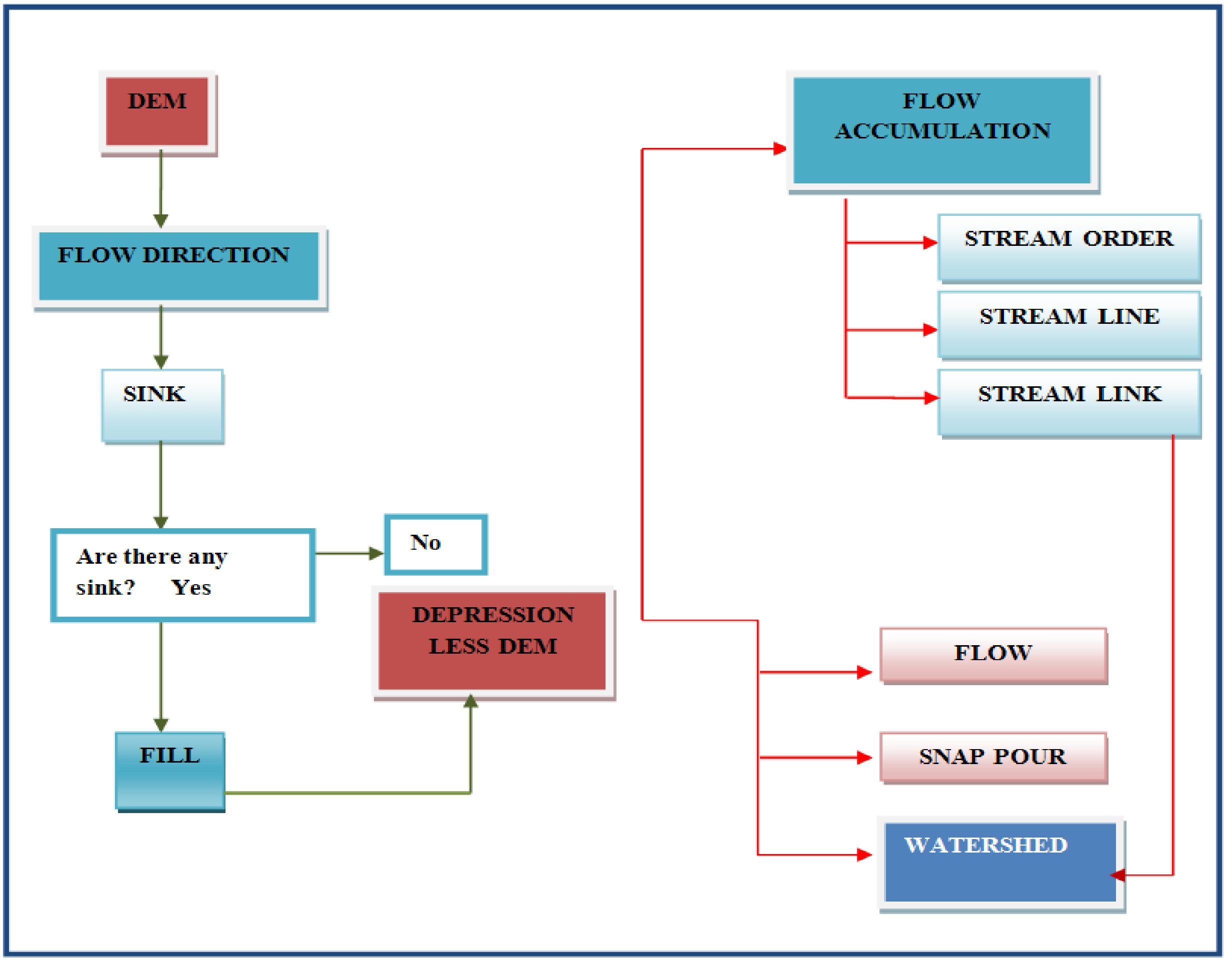

Fig. 3 Methodological scheme for hydrological modeling (Source, ESRI, 2011).

estimated watershed area is 14,386 km^2 (Sadaf, 2014). According to standard classification with respect to size, study area is categorized as a Macro Watershed (US EPA, 2008). Size of a watershed has direct effects on its different attributes like its storage characteristics, morphological and hydrological properties. Well-developed channel network and high storage are the main characteristics of a large watershed, which protects it from the effects of short spells of high precipitation. Whereas, a short spell of heavy precipitation has direct effect on small watershed (Youngbo and Florimond, 2004).

Digital elevation model can have errors. If some cells are in lower positions than others cells on any location in DEM, then water will move into the lower cells and will not be able to travel outside. These lower positions or depressions in elevation model are termed sinks, Hydrological modeling helps to identify such depressions or sinks, which are filled to make depression less elevation model (Fig. 4). Subsequently, flow direction is derived by this depression less elevation model.

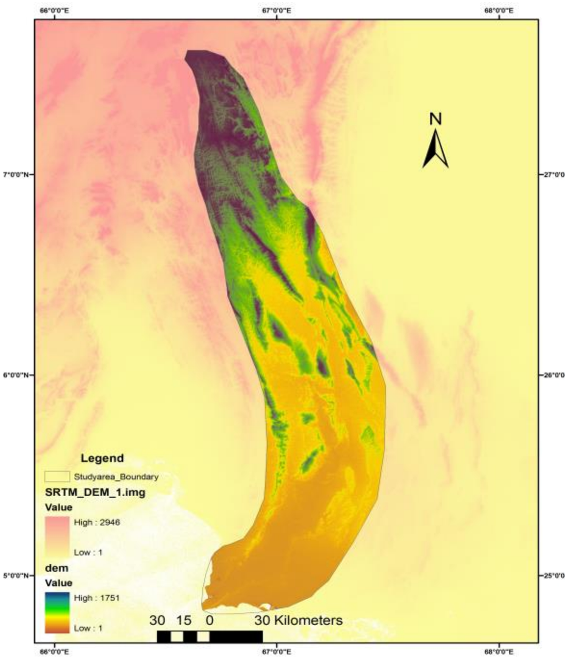

Fig. 4 SRTM image of the Hab Watershed.

Delineation of the Hab watershed

In GIS environment, hydrological modeling is performed and as a result complete drainage detail and boundaries of watershed have been obtained.

For the delineation of the watershed, some vital steps were performed like:

- Removal of depression from DEM and get depression less DEM,

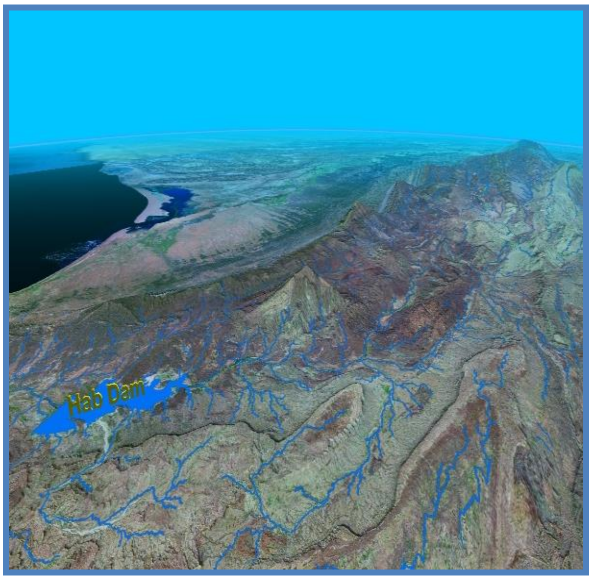

Fig. 5 3D view of the Hab watershed on Landsat image draped on SRTM data.

- Defining the flow direction and
- Flow accumulation per cell,
- Determination of flow length of the streams
- Establish the end limits of flow accumulation value, which represents the drainage pattern in the better way (Jenson and Dominique, 1988).

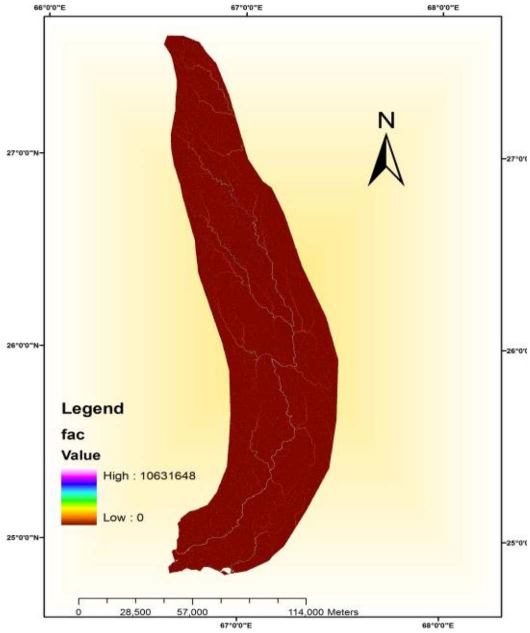

Fig. 6 Flow accumulation of streams in the Hab watershed.

For stream network creation, flow accumulation was calculated for study area (Fig. 6). Stream definition is an important characteristic of a watershed. It calculates all the stream grids, which has the value of "1" for all cells in the resultant flow accumulation grid and it has the greater value than the defined end limits. Other cells found in stream grid have no data.

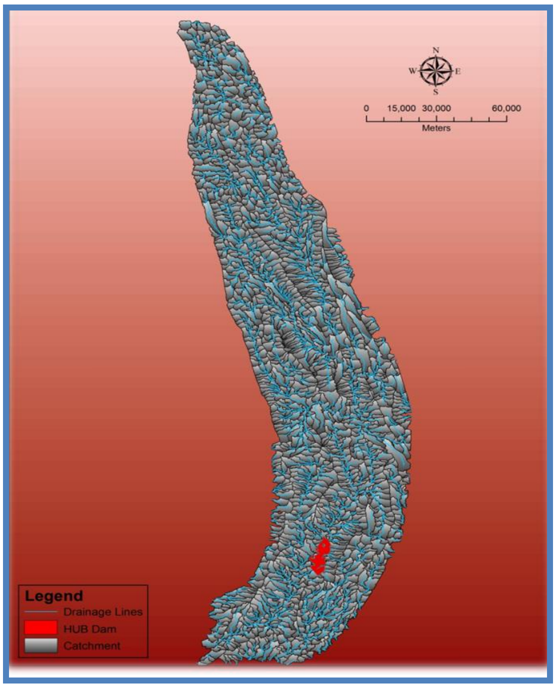

Fig. 7 Stream network delineation for the Hab watershed.

Selection of threshold value is also an important step for the delineation of watershed. It depends on the objective of study. If threshold value is small then it gives a dense stream network. Standard threshold value used with the national elevation dataset is 5,000 cells or 4.5 km^2 when the cells are 30 meters (Yunker, 2008).

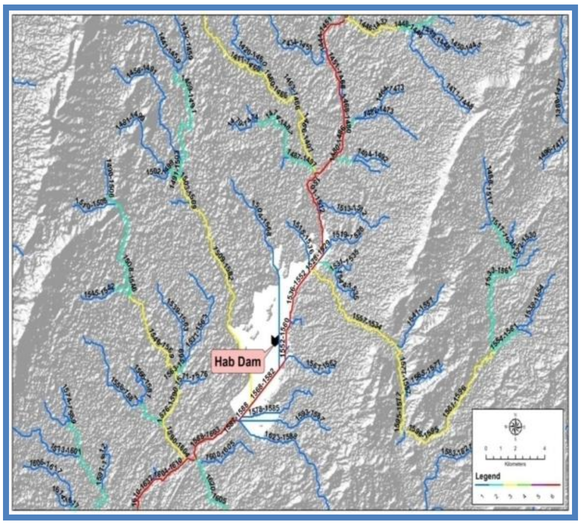

Fig. 8 Stream segmentation of the Hab watershed with specific grid code.

In the present study, a realistic model is prepared with detailed drainage, which potentially carries surface water to the reservoir (Fig. 7). Stream segmentation with unique identification, termed "grid code" was created. Through these grid codes complete stream network including main and small streams of the study area is clearly identified and defined (Fig. 8). All streams of a stream network have different Hydro IDs, Grid IDs and lengths, which represents the detailed picture of the complete drainage network of watershed.

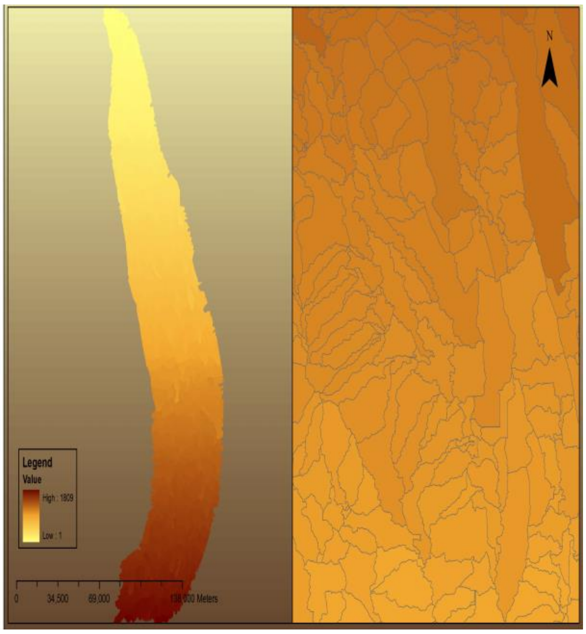

Fig. 9 Catchment grid delineation of the Hab watershed.

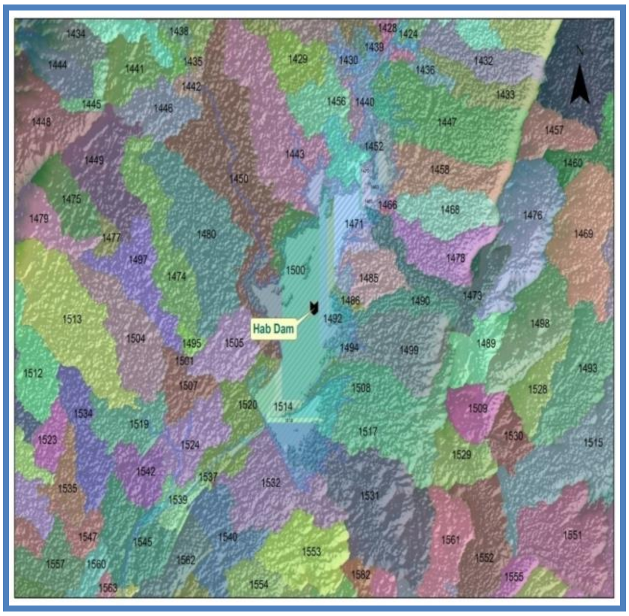

Fig. 10 Hab catchment delineation and its attribute.

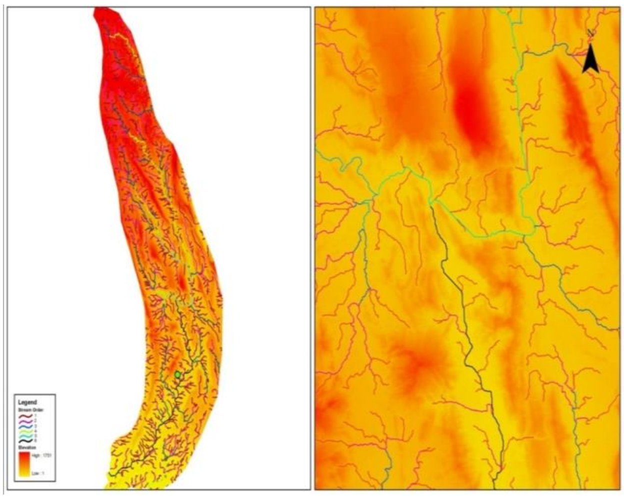

Fig. 11 Stream network of the Hab watershed calculated through hydrological modeling.

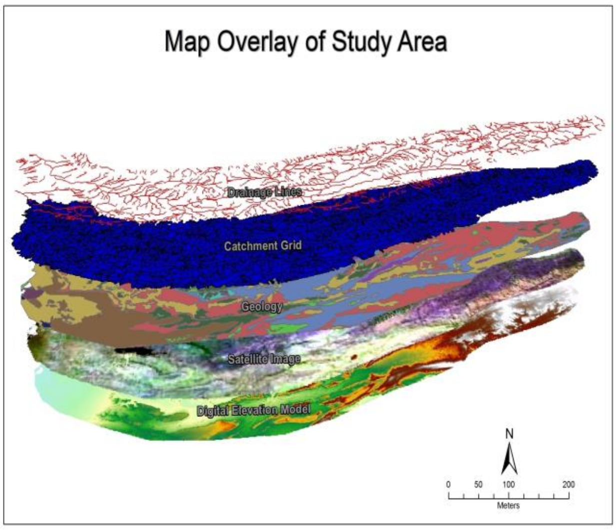

Fig. 12 Map overlay of study area.

Table 1. Key characteristics of the Hab watershed calculated through hydrological modeling.

Minimum (smallest catchment grid)	0.0009
Maximum (largest catchment grid)	62.8549
Sum (Total catchment grids in the study area)	1,809.0000
Mean	7.5852
Standard deviation	6.3845
Total length of drainage (km)	5,707.6362
Drainage density	0.3967
Total area of watershed (km^2)	14,385.9436
Total catchments grid area in Hab watershed (km^2)	13,721.6527

Catchment grid delineation

Catchment grid delineation function, created a grid for each catchment cell (Fig. 9) with a value (grid code). Catchment area is identified through this grid code and its value found in stream segment link grid (Fig. 10). Hydrological modeling of the study area provided some important findings, which are shown in Table 1. Detailed stream network till 6th order is calculated through hydrological modeling (Fig. 11). Map overlay is shown in Figure 12.

Conclusion

Hab watershed has been delineated through hydrological modeling and subsequently network extraction. Conversely manual extraction is a tedious, time consuming job and susceptible to mistakes. The results of the hydrological modeling are very satisfactory, detailed and speedy as compared to traditional methods.

Quality of analytical results is determined by the resolution and quality of DEM data. In this study 30 m DEM data was utilized. Results are reliable and provide a complete and detailed picture of the Hab Watershed. Based on size classification, Hab watershed falls into macro watershed (> 50,000 Hect) category. In GIS environment, Hab watershed boundaries are established and its area has been calculated.

Results from drainage analysis provided subsequently different datasets, which collectively describe the characteristics of the Hab watershed. Main characteristics of watershed include catchment segmentation, catchment delineation, stream network delineation and stream order etc. Owing to large size of study area, it would have been uphill task to calculate its stream order through traditional manual methods and delineate the basin. GIS provided an opportunity for calculation of the stream order of the watershed till 6th order, its distribution in sub-basins and accurate delineation. It has long catchment, therefore in rainy season, huge amount of water contributes the river, which flows from upper catchment area in south. The results demonstrate high capacity of ArcHydro for watershed simulation.

Drainage pattern of the Hab River shows that flow of the river is not smooth and straight from origin to the Arabian Sea. Characteristics of the watershed acquired from DEM data set in Table 1 show that the Hab Macro watershed has an area of 14,386 km^2 with 1806 small catchments and 0.4 drainage density, indicating huge potential of water resources, which need to be developed for satisfying the requirement of the region.

Acknowledgement

Author acknowledges the Federal Urdu University of Science and Technology, Karachi for the help and support during the Ph.D. studies.

References

Aftab, M. (1997). Hydrogeology and groundwater resources of Balochistan, Pakistan. *An Overview. ACTA Mineralogical Pakistanica,* **8,** 30-38.

Band, L. E., Moore, I. D. (1995). Landscape attribute and geographical information Systems. In: *Scale Issues in Hydrological Modeling. Advances in Hydrological Processes*. Willey and Sons, Chichester, **9**, 159-180.

Daily Express. (2016). Water supply to Karachi should be streamlined. http://tribune.com.pk. Accessed 23 March 2016.

Environment Systems Research Institute, (2011). *ArcGIS Desktop, Release 10*. ESRI Press, Redlands, CA.

Goodchild, M. F. (1993). Data models and data quality: problems and prospects. In: M. F. Good child; B. O. Parks and L.T. Steyaert (eds.), *Environmental Modelling with GIS,* Oxford University Press, New York, 8–15.

Grohmann, C. H. (2004). Morphometric analysis in geographic information systems: applications of free software. *Comput. Geosci.*, **30**, 1055–1067.

Javed, A., Khanday, M., Ahmed, R. (2009). Prioritization of sub-watershed based on morphometric and land use analysis using remote sensing and GIS techniques. *J. Indian Soc. Remote Sensing,* **37**, 261- 274.

Jenson, S. K., Domingue, J. Q. (1988). Extracting topographic structures from digital elevation data for geographic information system analysis. *J. Photogrammetric Engineering and Remote sensing,* **54** (11), 1593-1600.

Leipnik, M. R., Kemp, K. K., Loaiciga, H. A. (1993). Implementation of GIS for water resources planning and management. *J. of Water Resource Planning and Management*, **119** (2), 184–200.

Magesh, N., Chandrasekar, N., Soundranayagam, J. (2011). Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu, India: a GIS approach. *Environ. Earth Sci.*, **64**, 373–381.

Mark, D. M. (1984). Automatic detection of drainage networks from digital elevation models. *Cartographica*, **21**,168 -178.

Martz, L.W., Garbrecht, J. (1992). Numerical definition of drainage network and sub catchment areas from digital elevation models. *Computers and Geosciences*, **18** (6), 747-761.

McDonnell, R. A. (1996). Including the spatial dimension: Using geographical information systems in hydrology. *Prog. Physical Geography*, **20** (2), 159-177.

Moore, I. D., Grayson, R. B., Ladson, A. R. (1991). Digital terrain modeling: A review of hydrological, geomorphological and biological applications. *Hydrological Processes*, **5** (1), 3-30.

Sadaf, R. (2014). Watershed modeling of Hab River valley, Baluchistan Pakistan through RS and GIS Techniques. *Unpublished Ph.D. Dissertation*. Department of Geography, University of Karachi.

Sreedevi, P. D., Sreekanth, P. D., Khan, H. H., Ahmed, S. (2013). Drainage morphometry and its influence on hydrology in a semi-arid region: using SRTM data and GIS. *Environ Earth Sci.*, **70**, 839-848.

Thomas, J., Joseph, S., Thrivikramji, K., Abe, G., Kannan, N. (2012). Morphometrical analysis of two tropical mountain river basins of contrasting environmental settings, southern Western Ghats, India. *Environ Earth Sci.*, **66**, 2353-2366.

Tribe, A. (1991). Automated recognition of valley heads from digital elevation models. *Earth surface processes and Landforms*, **16**, 33-49.

United States Geological Survey (2014) Landsat images. http://earthexplorer.usgs.gov [Accessed 13/12/2015].

USGS, (2012). SRTM mission summary. https://lta.cr.usgs.gov [Accessed 22/12/2012].

United States Environmental Protection Agency (2008). *Handbook for developing watershed plans to restore and protect our waters.* EPA 841-B-08-002.

Water and Power Development Authority (WAPDA) Lahore, (1993). *Ground water Resources of Balochistan Province Pakistan.,*

Walsh, M. R. (1992). Toward spatial decision support systems in water resources. *Journal of Water. Resources Planning and Management*, **109** (2), 158–169.

World Health Organization (2009). *Guidelines for drinking-water quality (*4th Edition). Library Cataloguing-in-Publication Data. ISBN 978 92 4 154815 1 (NLM classification: WA 675).

Yongbo, L., Florimond, D. S. (2004). WetSpa Extension, A GIS-based hydrological Model for flood prediction and watershed management, *Documentation and User Manual*, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Belgium.

Yunker, D. (2008). ArcGIS Desktop discussion forums Esri. http://forums.esri.com/forums.asp?c=93